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IMP-I SPACECRAFT FINAL MAGNETIC TESTS

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— GODDARD SPACE FLIGHT CENTER —
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MAGNETIC TESTS Final Report
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GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

IMP-I SPACECRAFT
FINAL MAGNETIC TEST

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IMP-I SPACECRAFT
FINAL MAGNETIC TEST

PROJECT STATUS

This is the final report of the determination of the magnetic properties of the IMP-I protoflight spacecraft. After completion of this test the spacecraft, now designated as Explorer 43, was shipped to the Eastern Test Range and successfully launched on March 13, 1971.

PHOTOGRAPHIC COPY OF THE ORIGINAL DOCUMENT

IMP-I SPACECRAFT FINAL MAGNETIC TEST

SUMMARY

The increased IMP-J spacecraft spin axis moment (540 milliamperes-meter²) resulting from excessive field exposures during environmental testing substantiated the need for a final pre-launch magnetic deperm and measurement. By performing a dc rotation deperm it was possible to reduce this moment below the previous initial test post deperm magnitude. In addition, the magnetic field disturbance at the flight magnetometer diminished to below 0.1 nanotesla (gamma) in all directions.

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IMP-I SPACECRAFT (EXPLORER XLIII) FINAL MAGNETIC TEST

INTRODUCTION

In May 1970, an initial magnetic test was performed on the IMP-I spacecraft (Explorer XLIII) in the Spacecraft Magnetic Test Facility (SMTF). The test results* confirmed that the net spacecraft magnetic field disturbance at the flight magnetometer was within the design goal of 0.125 nanotesla (gamma). The final magnetic field measurement and deperm was performed in February 1971, prior to shipment to ETR launch site.

PURPOSE OF TEST

Test Objectives were:

- To determine the magnetic field disturbance of the integrated spacecraft at the flight magnetometer boom position.
- To remove the effects of any extraneous field exposures incurred during environmental testing.
- To establish that the post deperm remnant magnetization of the spacecraft does not exceed the initial test-final measurement levels.

TEST DESCRIPTION

The IMP-I spacecraft final magnetic test was performed in accordance with the attached procedure (DIRS #02326). A description of the facility, instrumentation, and test arrangement was included in the aforementioned initial test document (X-325-70-472).

INITIAL PERM

The first sequence of measurements which were performed on the IMP-I represented the "as received" or initial perm condition. Besides establishing

*IMP-I Spacecraft Initial Magnetic Test, X-325-70-472, October 1970.

the remnant magnetization, dipole moment and field magnitude at the onboard magnetometer, these measurements were to be used in determining if a spacecraft deperm would be required. The necessity for a deperm became evident when it was found that the field magnitude of the spacecraft had increased by a factor of eight over the previous post deperm field magnitude. In view of the fact that the spacecraft's field had increased to within 61% of the post 15×10^{-4} tesla (gauss) exposure level, it appeared that the spacecraft had been exposed to a sizeable field during vibration testing.*

DEPERM

Once it had been determined that the IMP-I would require a spin axis deperm, it was necessary to refixture the spacecraft on its steel handling dolly in order to tip the spacecraft on its side. After the spacecraft had been positioned in the center of the coil system, the facility horizontal axis deperm coils were rolled into place and equally spaced; in order to provide ample clearance when the spacecraft and dolly were rotated. The spacecraft was then depermed in the usual manner and retransferred to the facility dolly for remeasurement. A final, horizontal axis deperm was performed in order to remove any remnant magnetization irregularities which had been introduced by the steel dolly's residual field. Comparison of the boom mid-way distance fall-off data indicated that the Z-component magnitude had been reduced from 4.5 nanotesla (gamma) to ≤ 0.1 nanotesla (gamma) by the deperm treatment. As a result, the spacecraft field disturbance was considerably below the design goal level of 0.125 nanotesla (gamma).

STRAY FIELD

A spacecraft turn-on and subsequent measurement of the fields created during the operation of the spacecraft were performed and, once again, the effect of these fields were found to be minimal. During the course of the measurements, a more pronounced effect was produced as a result of spacecraft turn-on and off (post stray perm). At first this was attributed to interaction between the perm and stray fields of the spacecraft. However, it was finally determined that the flight turn-on plug was the culprit. Since these changes were relatively small, the effect would be undiscernable at the magnetometer.

*Memo Report: DIRS 01595 (Results of the Magnetic Field Surveys Conducted in T&E Environmental Test Facilities).

RESULTS AND DISCUSSION

As evidenced by the initial magnetic results, the IMP-I is a relatively non-magnetic spacecraft, having a net (post deperm) magnetic moment of 55 milliamperes-meter squared (pole-centimeters).

At the conclusion of the final test deperm treatments, the spacecraft dipole moment was found to be less than 50 mA-m² (pole-cm). Further evidence of the success of the deperms can be seen by comparing the pre and post deperm moment results listed in Table I. From the magnetometer standpoint, a moment of this magnitude would generate an equivalent magnetic field disturbance of less than 0.1 nanotesla (gamma) at the flight sensor location. In view of the fact that it is difficult to measure the 0.1 nanotesla (gamma) field, it is of advantage to utilize the intermediate distance measurement data. For example, the values listed in Table II represent the component magnitudes which were measured at both the actual and the mid-way distance. Assuming a $1/r^3$ fall-off, one would expect the mid-way values to be 8 times as large. By using this approach, it is possible to establish a maximum level limit. A more direct approach is to actually measure the field change with distance (fall-off) by monitoring the field as the spacecraft is moved away. The advantage of this technique can be seen in Figure 1 log plots. Here it is possible to see the rate at which the field decreases and, determine more accurately, the field disturbance at any particular location. This of course, is what is of most interest to the magnetic fields experimenter. Based upon the Figure 1 plots, it is safe to state that the maximum spacecraft field disturbance seen at the magnetometer (radial component field-H_x) would be 0.04 nanotesla (gamma). This, of course, is well below the magnetometer noise levels, and therefore satisfies the design goal requirements.

Table I

IMP-I Spacecraft Magnetic Moment

Magnetic Moment Values in Milliamperes Meter Squared (Pole-cm)

Magnetization	M _{xy}	M _z	M _t
Initial Perm	47	510	543
Post Spin Axis Deperm	40	44	59
Post Horizontal Axis Deperm	29	29	41

Table I (Continued)

Magnetization	M_{xy}	M_z	M_t
Post Stray Turn-on Plug In	65	29	71
Post Stray Turn-on Plug Out	36	29	46

Table II

IMP-I Spacecraft Magnetic Field

Magnetic Field Disturbance Levels

Magnetization	Component	Field Magnitude in Nanotesla (Gamma) At:	
		213 cm (84")	427 cm (168")*
Initial Perm	X	1.5	≤ 0.2
	Y	≤ 0.1	< 0.1
	Z	4.5	0.6
Post Deperm & Stray Field	X	≤ 0.2	< 0.1
	Y	< 0.1	< 0.1
	Z	0.4	< 0.1
Post Stray Deperm	X	0.5	< 0.1
	Y	< 0.1	< 0.1
	Z	0.1	< 0.1

*Flight Magnetometer Location

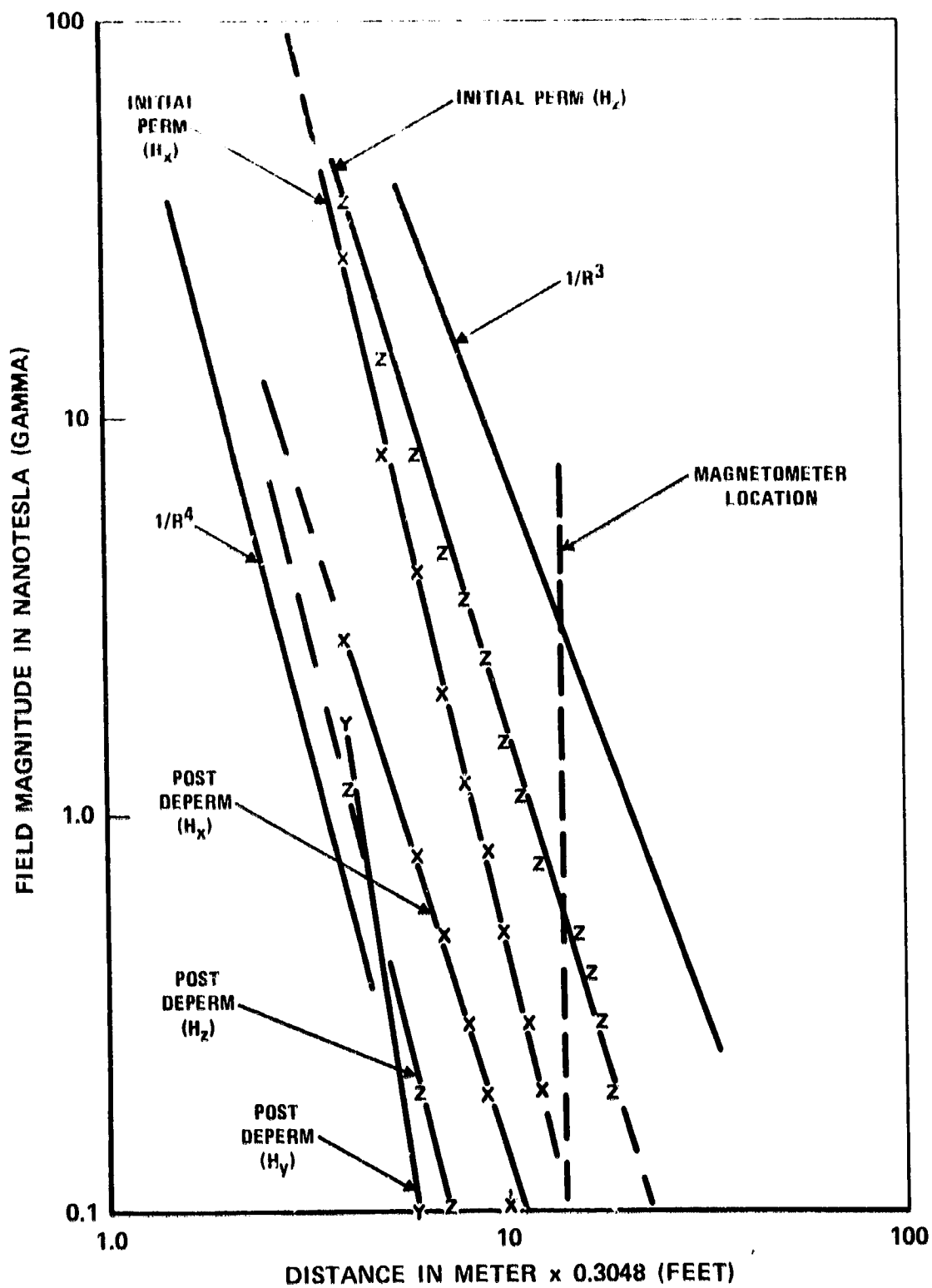


Figure 1. IMP-I Spacecraft Field Fall-Off Along Magnetometer Boom

APPENDIX A

DETERMINATION OF MAGNETIC FIELD DISTURBANCE AND NET DIPOLE MOMENT OF THE IMP-I SPACECRAFT

1.0 PURPOSE OF TEST

1. To demonstrate that the spacecraft field disturbance at the position of the in-board magnetometer is within flight acceptance threshold levels.*
2. To determine the net spacecraft dipole moment.
3. To calibrate the in-board magnetometer.

2.0 TEST DESCRIPTION

1. Permanent Magnetization

- a. Initial Perm "as received". The "as received" magnetic state of the spacecraft indicates:
 - (1) A possible level of perm which the newly assembled spacecraft might be expected to maintain.
 - (2) A relative magnitude of field which can be used to determine the effectiveness of the deperm treatment.
 - (3) Stability of spacecraft perm field by initiating a record of its magnetic history.

2. Post Deperm

The magnetic state of the spacecraft is determined after being demagnetized in a diminishing field which had an initial magnitude of ≤ 30 gauss.

*These threshold levels are defined as either a field of 1/8 gamma or less for all 3 sensors (X, Y & Z) or as a moment of 84 pole-cm or less along the Y and Z axis and 42 pole-cm along the +X axis.

3. D.C. Stray Field Magnetization

- a. External Power — the magnetic state resulting from current circulating within the spacecraft due to the operation of on-board equipment and experiments will be determined.
- b. Spacecraft Battery Power Usage — the magnetic state of the spacecraft is determined using spacecraft battery power which will produce circulating currents within the spacecraft as a result of the operation of on-board spacecraft experiments and equipments.

4. Magnetometer Calibration

The spacecraft magnetometer calibration shall be performed in order to determine the following characteristics of each magnetometer sensor (X, Y and Z).

- a. Zero Offset
- b. Sensor Alignment
- c. Calibration Linearity
- d. In-Flight Calibration
- e. Spacecraft Spin Simulation
- f. Flipper Operation
- g. Noise Level

During the calibration the spacecraft shall be offset from the center of the coil and in an orbital configuration with the exception of the EFM and loop antennas.

2.1 TEST FACILITY

The measurements are to be conducted at the GSFC Spacecraft Magnetic Test Facility, Building 305, as shown in Figure No. 1. This facility includes a 42 foot coil system with provisions for nulling the ambient geomagnetic field to zero with a uniformity of 0.001% over a spherical volume 7 feet in diameter. This facility is equipped with the following:

- 1 - Coil system, 42 foot in 305 building.

- 2 - Perm/deperm coil, 9.4 foot diameter.
- 4 - Fluxgate magnetometers, Forster-Hoover MF 5050.
- 1 - Single axis detector, Schoenstedt, Model SPM 43B-2.
- 4 - Tripole detectors (X, Y, Z probes), Forster-Hoover MF-T-165.
- 1 - Proton Magnetometer Varian V4931DR.
- 1 - High Speed Data Acquisition System (MADAS).
- 2 - Strip Chart Recorders, Brush 8 Channel Model 200.
- 1 ea - Dolly, turntable, and spacecraft mounting fixtures.
- 1 - Perm/deperm coil (with d.c. power supply).

2.2 MODIFICATION OF PROCEDURES AND EQUIPMENT

The magnetic test facility detailed test procedure, test sequence, or appropriate equipment may be modified at the discretion of the magnetic test facility cognizant engineer as practise dictates. All changes related to the spacecraft must receive the concurrence of the IMP project engineer prior to incorporation.

2.3 SPACECRAFT TEST CONDITION

The spacecraft subsystems will be in operational configuration which duplicates the actual orbit configuration. This will include solar panels connected, batteries connected, telemetry, and the experiments operated by command.

Electric power will be supplied to the spacecraft by an external source through twisted leads carefully dressed to minimize stray field.

2.4 SPACECRAFT PRE/POST OPERATIONAL TEST

The spacecraft will be given a modified Functional Test prior to magnetic testing, and immediately after conclusion of the magnetic measurements.

3.0 TEST PROCEDURE

1. Test Facility Set-Up

- a. Set up four tripole detectors on a north horizontal line passing through the approximate center of the magnetic mass of the spacecraft. All detectors should be on the same side of the spacecraft spaced at distances of 4, 6, 8, and 13.5 feet from the center of the coil system. These distances should be measured from the middle probe on the detectors and should be positioned so that the long side is vertical and the X, Y and Z probes are oriented to the H, D and Z coil axis respectively.
- b. Connect the magnetometers and recorders such that simultaneous recordings may be made of the signals from the four detectors.
- c. Insure that the spacecraft is removed from the coil system.
- d. Set up Schoenstedt detector in the center of the coil system.
- e. Energize all test equipment and adjust the current in the coil system coils until the Schoenstedt magnetometer indicates a zero field (0 ± 0.5 gamma). (This can be done by flipping the detector 180° back and forth.)
- f. Adjust gradient cancelling coils to minimize gradient over central volume.
- g. Remove the center detector and zero the magnetometers for the four test detectors by setting in the necessary compensation. Calibrate the magnetometers and analog and digital recorders.

2. Spacecraft Set-Up

- a. Deposit the spacecraft on the SMTF loading platform.
- b. Roll the spacecraft dolly into the SMTF truck lock and equally position the dolly wheels east/west over the center of the rails.
- c. With the truck lock traveling hoist at the north end of the truck lock, lower the hoist and attach the spacecraft lifting sling. Raise the sling to the maximum overhead height.

- d. Move the truck lock hoist to a position directly above the spacecraft dolly.
- e. Lower the lifting sling. Caution -- the hoist remote control push button station has two operating speeds: slow (6 feet per minute) and fast (19 feet per minute). Initial depression engages the slow speed drive. Full depression produces fast travel.
- f. Secure the lifting sling to the spacecraft. Apply tension to the spacecraft to release it from the dolly. Remove the marmon clamp and raise the spacecraft until it clears the spacecraft dolly.
- g. Translate the spacecraft to the north end of the truck lock. Roll the SMTF dolly beneath the spacecraft.
- h. Lower the spacecraft onto the turntable and with the spacecraft -X axis aligned with 0° on the dolly turntable, bolt the spacecraft mounting ring to the turntable.
- i. Release the spacecraft sling and move the overhead hoist to the south end of the truck lock.
- j. Connect SMTF grounding strap to the spacecraft mounting ring.
- k. Connect 28.5 volt power to the spacecraft using the inflight disconnect as a means of power insertion. Verify telemetry and command unit.
- l. Remove spacecraft power unit cable. The spacecraft is now ready to start magnetic testing.

NOTE: Magnetic checks have been performed on the protective solar panel covers indicating that they are non-magnetic (< 0.1 gammas at 2") and can be left in place during magnetic testing.

3. Permanent Magnetization

a. Initial

- (1) Turn on data acquisition equipment and allow them to run for 30 minutes warm-up to obtain reliable data. Establish zero field and rezero the magnetometers by setting in the necessary compensation. Calibrate the magnetometers. Then move the spacecraft

into the coil system and align the spacecraft at the zero degree reference position.

- (2) Record the field observed at each detector with the spacecraft in this position.
 - (3) Spacecraft rotation data: Rotate the spacecraft 360° in azimuth indexing the recorders at each 10° increment of rotation while recording field changes at all detectors.
 - (4) Spacecraft fall-off data: With the data system operating move the spacecraft and dolly from the center of the coil system indexing the recorder at each 1 foot interval.
 - (5) Recheck magnetometer zeros.
- b. Deperm — if the field as detected by the Z axis sensor at the on-board magnetometer position exceeds 0.125 gammas (84 pole-cm) the spacecraft shall be given a Z axis deperm treatment. Appendix A describes this procedure.
- (1) Move the spacecraft into the deperm coil system.
 - (2) Deperm the spacecraft in a diminishing field with initial magnitude of ≤ 30 gauss.
 - (3) Rotate the spacecraft 360° in azimuth indexing the recorders at each 10° increment of rotation while the recording field changes at all detectors.
 - (4) Remove spacecraft from coil system while obtaining fall-off data.
 - (5) Shut down the recorders.

4. Stray Field

a. External Power Measurement

- (1) Move the spacecraft into the center of the 42 foot coil facility and ensure that the spacecraft is at the zero degree reference position.
- (2) Lower the clean room tent to the floor and turn on the blower. Remove spacecraft cover.

- (3) Apply power to the spacecraft through the inflight disconnect cord.
- (4) All operational functions of the spacecraft will be performed in order to determine the effect of circulating currents on the spacecraft's magnetic field.

5. Magnetic Measurements Using Batteries as Source of Power

The spacecraft batteries shall be connected in such a manner as to provide the basic power to the spacecraft. These batteries shall be charged in such a manner as to have full capacity available for performance of these tests. The external power source provided by the umbilical plug shall be removed during the course of this test.

Major functions of the spacecraft shall be performed to determine difference, if any, from results obtained in 5a above.

6. Magnetometer Calibration

- a. Reinstall solar cell covers and spacecraft cover.
- b. Raise clean room tent.
- c. Position the spacecraft so that the sensor package is in the center of the coil system with boom fully deployed. Align the spacecraft with the coil system axis (spacecraft X axis directly north-south).
- d. With the spacecraft on and transmitter off, adjust the coil system for zero magnetic field (± 0.5 gamma). Check and minimize all gradients.
- e. Remove the external magnetometer, turn on the spacecraft transmitter, and prepare for telemetry output from the in-board spacecraft magnetometer.
- f. Apply d.c. fields from 0 to $\pm 1,000$ gammas along each axis as required to establish sensor alignment, linearity, and zero. Telemetry data will be obtained during the calibration sequence as the fields are applied along each axis (X, Y, and Z) for each of the four magnetometer ranges. Magnetometer flipper operation and inflight calibrations shall be an integral part of the calibration sequence.
- g. Spacecraft spin simulation shall be provided by applying a 5 RPM rotating field in the H-D plane.

SPACECRAFT MAGNETIC
TEST FACILITY

3 AXIS GYROSCOPE COIL
SYSTEM WITH COILS OF
42 FT. DIA. DIA.

WINDUP FOR CENTRAL
BOAST

WINDUP FOR GENERAL
OR SPACECRAFT

EQUILIBRIUM COILS

MAXIMUM OPENING
THROUGH COILS
16' x 16''

TRUCK-LOCK
TRAVELING
BOAST

DOLLY CARRYING TRACKING
& MEASURING EQUIPMENT

Figure A-1. SMTF Coil System

APPENDIX B

SPIN AXIS DEPERM TEST PROCEDURE

The following modified test procedure shall be incorporated into the initial test post deperm sequence if it becomes necessary to perform a spin axis deperm.

1. Spacecraft Set-Up

- a. The spacecraft must be removed from the SMTF nonmagnetic dolly and replaced on the spacecraft dolly. The procedure shall be in reversed order for the sequence in 3.2, but with the spacecraft dolly in reversed positions.

2. Deperm

- a. Move (magnetic) spacecraft dolly into center of coil system.
- b. Position the dolly on the turntable.
- c. Lower the 4 dolly jacks and support the spacecraft on the two 2" x 6" wooden turntable braces. Remove dolly running.
- d. Tip the spacecraft 90° (spin axis horizontal) and prepare for a rotation deperm (probably should tip over before entering coils).
- e. Generate a 30 gauss d.c. field with the deperm coil. Run the spacecraft rotation speed to a maximum of 9.5 RPM. Remove the d.c. field while continuously rotating the spacecraft.
- f. Return the spacecraft to the SMTF dolly for the post deperm measurements.